Varanus cerambonensis on the island of Buru. *Photograph by Valter Weijola.*

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A single species of mangrove monitor (*Varanus*) occupies Ambon, Seram, Buru and Saparua, Moluccas, Indonesia

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***Abstract.*—According to current literature the islands of the central Moluccan region harbor at least three species of monitor lizards. This suggests similar patterns of species richness to the northern Moluccas and could imply significant taxonomic and ecological complexity throughout the Moluccan region. Field investigations in habitats from sea level up to 300 m elevation failed to locate more than one widespread species, by definition referable to *Varanus indicus* (type locality Ambon). Reassessments of records for other species of mangrove monitors show that these can either be attributed to taxonomic mis-identifications or to colonial-era specimens lacking reliable collection data. We test Principal Components Analysis of scalation characters as a diagnostic tool for some of the island populations and species within the *Varanus indicus* group.**

Key words. Monitor, *Euprepiosaurus*, *Varanus indicus*, *Varanus cerambonensis*, *Varanus rainerguentheri*, Moluccas, habitat use

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Introduction

The island of Ambon has had a history of commercial and strategic importance and has been connected to the European economy for five centuries. As a consequence, many early faunal collections came from there, and it is the type locality for a considerable number of Indonesian species, some of which have proved to be native to the island whereas others were merely shipped from Ambon (e.g., Daan and Hillenius 1966; Hoek Ostende et al. 1997). Despite this long European presence, little first-hand information has been published on the biology of the local *Varanus* species. The first recorded observations and possible specimen collection of monitors on Ambon were made in 1792 by Claude Riche, one of the naturalists of the d'Entrecasteaux Expedition, and reported by F.M. Daudin in the description of *Tupinambis indicus* a decade later (Daudin 1802). For the next two hundred years this was the only species reported from the central Moluccas (to which we refer to the islands of Seram, Buru, Ambon, and the other islands in the Lease group).

This changed when Philipp et al. (1999) revised the identity of *V. indicus* and described a second species from Ambon, Seram, and Buru, which they named *V. cerambonensis* (Fig. 1 A–D), distinguishable from *V. indicus* through the presence of a yellow temporal stripe, a banded dorsum, and a bi-colored tongue. In 2012 Somma and Koch reported that a third species, *V. rainerguentheri* (Fig. 1 E–F), also occurs on Buru in sympatry with *V. cerambonensis* (and possibly *V. indicus*). *Varanus salvator* has also been reported to occur on Seram on the basis of a single voucher specimen (Koch et al. 2007). These records are discussed here and Principal Components Analysis (PCA) is tested as a tool to detect differences between island populations of species in the *V. indicus* group (Fig. 2).

With a surface area of 17,400 km² Seram is the second-largest island in the Moluccas (after Halmahera) (Monk et al. 1997). It is estimated to have emerged as a land mass around 5–6 MYA along the Outer Banda Arc and rotated westward (Hall 2002), thus always having been isolated from New Guinea (Audley-Charles 1993; Fortuin and de Smet 1991). For animal groups with good dispersal abilities, such as Lepidopterans, this appears to have had little impact on current diversity and community composition when compared to the slightly larger

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Fig. 1. Mangrove monitors and their habitats: *V. cerambonensis* on Ambon **(A)**, Seram **(B)**, and Buru **(C, D)**. *Varanus rainerguentheri* on Halmahera **(E)** and Obi **(F)**. Coastal vegetation on Ambon **(G)** and Nipa swamp **(H)**. *Photographs by Valter Weijola.*

island of Halmahera (de Jong 1998). For monitors specifically, the lack of a land connection with New Guinea appears to have restricted the number of successful colonizers to just one (this study) whereas the composite island of Halmahera has a larger set of species (Weijola 2010).

There are strong patterns in the distribution of the members of the subgenus *Euprepiosaurus*, the Indoaustralian radiation of gracile terrestrial and arboreal species containing mangrove and blue-tailed monitors and the slender tree monitors of the *V. prasinus* group. Members of the latter clade are largely restricted to landmasses on the Sahul shelf. The blue-tailed monitors in the *V. indicus* group (*V. caerulivirens*, *V. doreanus*, *V. finschi*, *V. jobiensis*, and *V. yuwonoi*) show a similar pattern, with the exceptions of also inhabiting Halmahera (and adjacent islands) as well as the island of New Britain (Ziegler et al. 2007). The only lineage with a demonstrated ability for significant oversea dispersal is that mainly inhabiting coastal areas, traditionally known as a variable and widespread mangrove monitor, *V. indicus*. This lineage, with one representative in the central Moluccas, has lately been split up into several closely related species that all appear to exhibit allopatric distributions: *V. cerambonensis* (Buru, Ambon, Lease Islands, Seram); *V. indicus* (Australia, New Guinea, and satellite islands, as well as many Pacific islands); *V. melinus* (Mangole and possibly Taliabu); *V. juxtindicus* (Rennell); *V. rainerguentheri* (northern Moluccas); *V. lirungensis* (Talaud); and *V. obor* (Sanana) (Fig. 3). Additional populations of uncertain status occur in the Aru, Kei, and Tanimbar island groups.

In 2008 to 2009 fieldwork was conducted to study the niche partitioning among monitor species on several Moluccan islands (Weijola 2010; Weijola and Sweet 2010). On Ambon, Seram, Saparua, and Buru the species communities were initially presumed to be composed of *V. indicus* utilizing coastal habitats and *V. cerambonensis* occupying habitats farther inland as suggested by Philipp et al. (1999) and mirroring the ecological roles of *V. rainerguentheri* and *V. caerulivirens* on Halmahera (Weijola 2010) or *V. indicus* and *V. jobiensis* on New Guinea (Philipp 1999). This hypothesis was rejected during fieldwork as it became evident that only one of the species, *V. cerambonensis* (*sensu* Philipp et al. 1999), functioned as a habitat generalist and occurred throughout each island, and that *V. indicus* (*sensu* Philipp et al. 1999) was absent from these islands altogether.

The absence of *V. indicus* (*sensu* Philipp et al. 1999) is problematic inasmuch as Ambon is the type locality for this species. The only two specimens, ZMA 11146c and ZFMK 70650 (formerly ZMA 11146d), indicating a sympatry between *V. indicus* and *V. cerambonensis* on Ambon (and in the central Moluccas) turned out to have belonged to a colonial-era collector stationed on Ambon, but there is no evidence to suggest that they were actually collected there. The identity of *V. indicus* has been reviewed in detail by Weijola and a Case to synonymize *V. cerambonensis* with *V. indicus* has been submitted to the International Commission on Zoological Nomenclature (ICZN) (Weijola, *In press*). As this nomenclatural issue is yet to be resolved we follow the current name uses and diagnoses here but note that future changes are possible.

Methods

Fieldwork was conducted during March and December 2009 near the following settlements: Ambon – Liang (VW); Hitu (VW, SS); Soya di Atas (VW, SS); upper Ambon Bay (VW, SS); Waitami (VW, SS); Latuhalat (VW, SS); Seram (VW) – Besi; Buru (VW) – Namlea, Wamlana, Samleko; and Saparua (VW, SS) – Kulur. Species identification in the field followed the diagnostic characters provided by Philipp et al. (1999). Accordingly *Varanus cerambonensis* can be identified by its distinct yellow temporal band and yellow markings (dots and/or ocelli) arrayed in a pattern of transverse bands on the dorsum. These characters can effectively be used in the field even at a distance with a pair of binoculars.

Observations on habitat use were obtained by quietly traversing all major habitat types from coastal (mangroves, natural coastal scrub, coconut plantations, parklands) to lowland rainforests and hill forests up to 300 m elevation. Searches were made on foot or by canoe. For each observation date, time, location, habitat, and vegetation type, altitude, and activity were recorded. Active animals could often be heard running through dry litter in the undergrowth before fleeing up a tree where their identity could be confirmed. Basking animals often remained still unless approached within flight distance (normally 10–30 m).

The examination of museum vouchers allowed for a larger set of characters including scale counts to be assessed. According to Philipp et al. (1999) *V. cerambonensis* has on average smaller scales and higher scale counts than does *V. indicus*: e.g., scales around midbody (131–150 vs. 106–144), or transverse rows of dorsal scales (126–163 vs. 105–137).

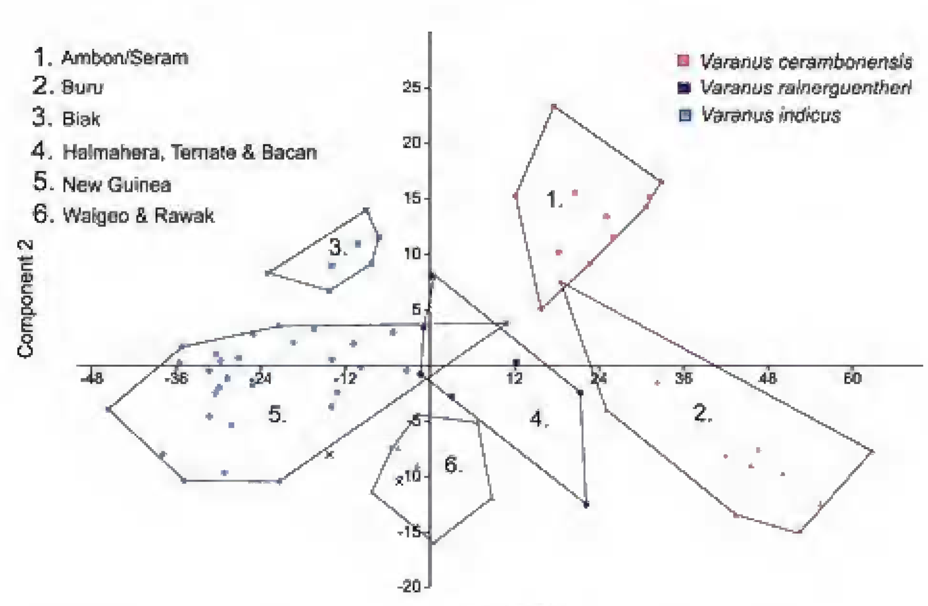

Fig. 2. Principal Components Analysis of scalation characters for several island populations of *V. cerambonensis*, *V. indicus*, and *V. rainerguentheri*. The two Xs represent ZFMK 70650 and ZMA 11146c.

Museum specimens at Naturalis (RMNH) and the Zoological Museum Amsterdam (ZMA) were identified (VW) and scale counts for a Principal Components Analysis were extracted from Brandenburg (1983). Counts employed were: midbody scale rows (S), dorsal scale rows from dorsal margin of tympanic recess to anterior margin of hind limbs (XY), transverse rows of ventral scales from gular fold to anterior margin of hind limbs (T), transverse rows of dorsal scales from posterior margin of tympanic recess to gular fold (X), scales around neck at anterior margin of gular fold (m), scales from rictus to rictus across dorsum of head (P), scales around tail base (Q), scales around the tail 1/3 from the base (R), and number of ventral scales from the tip of snout to gular fold (N).

Principal Components Analysis was performed in PAST (Hammer et al. 2001) using all the above-mentioned scale characters for specimens from Ambon, Seram, Buru, Halmahera, Ternate, Bacan, New Guinea, Waigeo, and Biak (Appendix 1).

Results

Morphology

The Principal Components Analysis of scalation characters (Fig. 2) worked well to differentiate the included island populations with partial overlap found only between *V. rainerguentheri* and *V. indicus*. PC1 and PC2 accounted for almost 90% of the total variance. The factor loadings for PC1 were all positive with highest values on factors XY (0.78) and S (0.42). On PC2 all loadings were positive except for XY and R, with highest values on T (0.71) and m (0.61). PC3 gave more overlap between the population clusters. Eigenvalues and factor loadings for PC1–PC3 are presented in Table 1.

Habitat use

All field observations, involving a total of 81 sightings (Ambon, 31, Buru, 21, Seram, 9, and Saparua, 20) were identified as *V. cerambonensis*. Monitors were most numerous on Ambon, Buru, and Saparua whereas fewer observations were made on Seram. A majority of observations (n = 70) was made in coastal areas where monitor population densities appear to peak. Encounter rates were high both in littoral forest (n = 38) in sandy and karst (n = 9) areas, as well as in mangroves (n = 14) and Nipa swamps (n = 9). The preferred areas usually had a bushy undergrowth used for hiding and larger trees for basking and hiding in tree cavities. Seven observations were made in coconut or mixed-crop plantations in lowland areas.

Far fewer monitors were observed in lowland rainforests (n = 1), swamp/sago forest (n = 1), and hill forests (n = 2), with the highest altitude observation at around 300 m near a small stream at Soya di Atas on Ambon. There

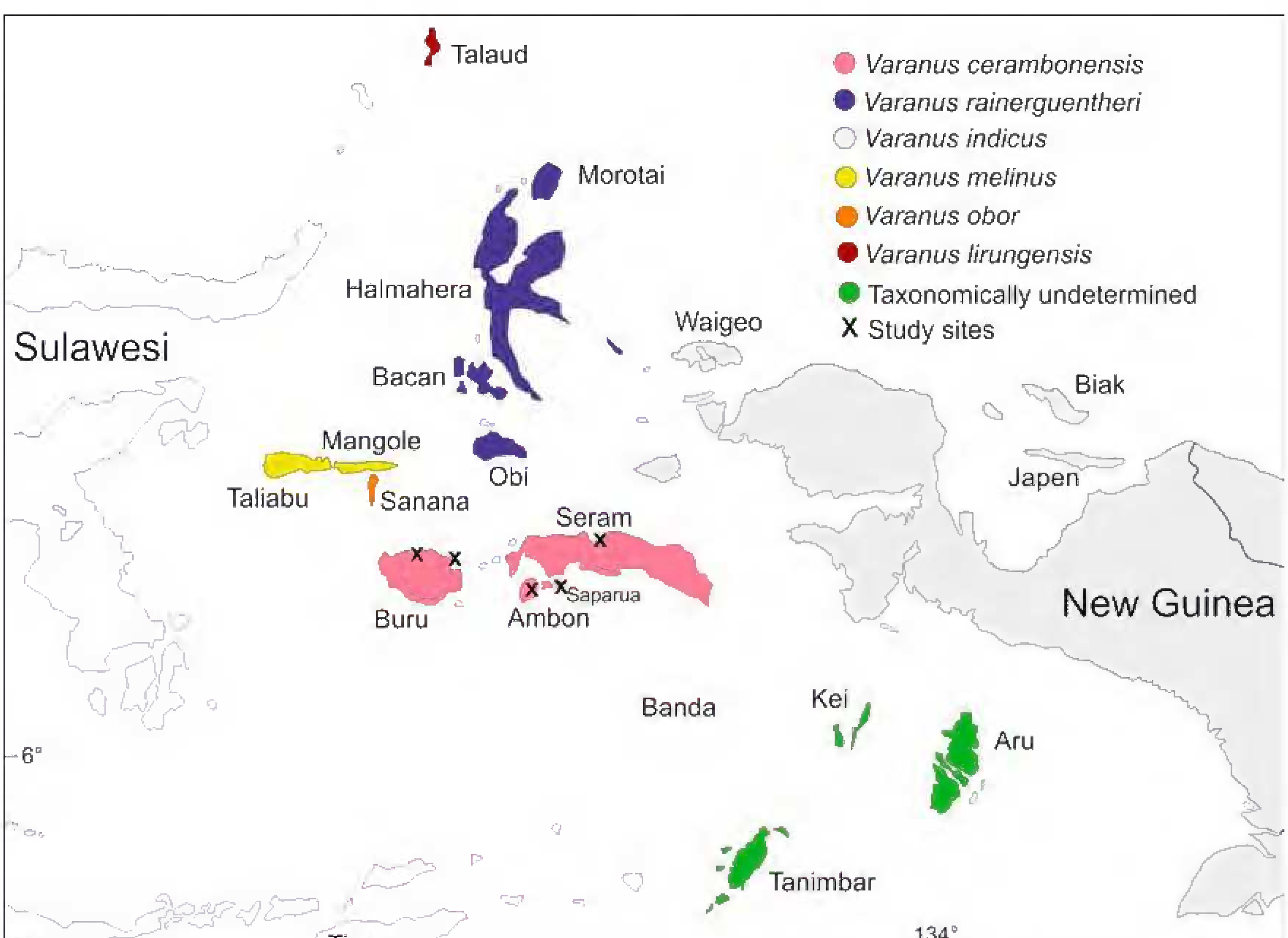

Fig. 3. Distribution map of mangrove monitors in the Moluccas and western New Guinea, the blue tailed monitors not included.

Table 1. Loading values, proportion of variance, and eigenvalues for PCA. The two highest loading factors on the three first components highlighted.

Factor	Comp 1	Comp 2	Comp 3
P	0.111204	0.099216	-0.054745
Q	0.19027	0.24899	**0.3686**
XY	**0.77924**	-0.57179	-0.10626
m	0.36133	**0.60913**	-0.23433
S	**0.41622**	0.45941	0.036529
T	0.27334	**0.71204**	0.1145
N	0.16643	0.10618	0.15529
R	0.0088444	-0.052658	**0.8697**
Proportion of variance	81.245	8.594	4.1006
Eigenvalue	711.843	75.2985	35.9281

is however an almost fully melanistic specimen (ZMA 15416g) at the Naturalis Museum collected at Lake Rana on Buru (at 770 m elevation) which shows that the species also occupy higher altitudes.

Activity and foraging

Fifty-six of the monitors were first observed while actively moving or foraging on the ground whereas the other 25 were first seen while basking on tree trunks/branches (n = 21) or on the ground (n = 4). Monitors usually became active and emerged to bask at around 0815–0845 and returned to their retreats late in the afternoon, the latest observation of an active individual was made on Ambon at 1600. The only specific foraging events observed during this study were several specimens on Buru actively digging out sea turtle nests in search of eggs, one individual on Seram digging for sago grubs in a rotten Metroxylon trunk, and another individual (also on Seram) digging through a pile of garbage at the edge of a mangrove swamp.

Discussion

Natural history

Observations of habitat use of *V. cerambonensis* correspond well with that reported from field studies of mangrove monitors (*V. indicus senso lato*) in other regions (Iyai and Pattiselanno 2006; Philipp 1999; Smith and Griffiths 2009; Weijola 2010). Densities appear to peak in coastal and saltwater influenced areas with suitable vegetation cover and decrease with increasing altitude where animals also become more restricted to areas near bodies of freshwater. Dietary studies show *Varanus cerambonensis* to be an opportunistic predator with the single largest component being crustaceans which makes up almost half of the diet (Philipp et al. 2007). As is usual throughout the Moluccas monitors were more frequently encountered near Muslim than Christian settlements, presumably reflecting dietary restrictions and the scarcity of hunting dogs.

In more species rich-communities such as that of Halmahera, mangrove monitors (on Halmahera *V. rainerguentheri*) are rarely observed at higher altitudes where instead *V. caerulivirens* is common (Weijola 2010). *Varanus indicus* on New Guinea may similarly be restricted in upland areas by competition from *V. jobiensis* and *V. doreanus*. On some single species islands the mangrove monitors appear to persist higher up and can occasionally be found up to at least 700–900 m elevation (as demonstrated by their presence at Lake Rana on Buru). On New Ireland, Papua New Guinea, the senior author has collected mangrove monitors as high up as the Lelet Plateau at 900 m elevation (Weijola, *unpub. data*).

Biogeography

Whereas many of the larger islands in the northern Moluccas (e.g., Halmahera, Obi, Bacan, and Morotai), and island arcs moving along the northern coast of New Guinea, have several monitor species with evident ecological specialization (Weijola 2010), the other Moluccan islands, including Ambon, Seram, Buru, Tanimbar, and Kei, have only single members of ecological generalists of the *V. indicus* group present (this study; Weijola, *unpub. data*). These are joined by members of the *V. salvator* group in the Sula islands and on Obi (Weijola 2010; Weijola and Sweet 2010), but the presence of *V. salvator* on Seram (Koch et al. 2007) has not gained support from recent fieldwork (Edgar and Lilley 1993; this study) and they were unknown to several experienced hunters contacted by VW. This is usually a conspicuous animal wherever it occurs; for example, the new records for Taliabu and Sanana were established on the first and second days of fieldwork (VW and SS), on the first day on Mangole (VW) and on the second day on Obi (VW).

Varanus rainerguentheri

Somma and Koch's (2012) distribution record of *V. rainerguentheri*, and their claim of its co-existence with *V. cerambonensis*, on Buru is based on a preserved specimen (Senckenberg Museum, Frankfurt [SMF 56469]) and a photo taken in the field (Somma and Koch 2012, Fig. 6). Both were identified as *V. rainerguentheri* from the occurrence of rows of dorsal ocelli. However, there are eleven vouchered *Varanus* from Buru at the Naturalis Museum (ZMA 15416a–j, RMNH 7223), which are similar in color pattern to those presented as *V. rainerguentheri* by Somma and Koch, and which were examined and identified as *V. cerambonensis* by Philipp et al. (1999) (forming the record of *V. cerambonensis* for that island). All above-mentioned specimens conform in color pattern to those observed in the field during this study. As is indicated by Weijola (2010) there are typically no

distinct bands of dorsal ocelli on adult *V. rainerguentheri* but these are instead characteristic of the *V. cerambonensis* populations on Ambon and especially Buru (ZMA 15416, Weijola field observations). For these reasons we regard Somma and Koch's records of *V. rainerguentheri* from Buru to be mis-identifications of *V. cerambonensis*.

Principal Components Analysis

The results of the PCA illustrates its potential to recover geographic clusters among the sampled islands. As the increasing number of island endemics and cryptic species has made identifications more problematic, and the use of single color pattern characteristics can be misleading, we acknowledge its usefulness as an additional diagnostic tool.

Although considered conspecific the distance between the Ambon/Seram and Buru populations detected by the PCA indicate morphological separation between the two populations. In addition to scalation differences the population of Buru also differ in color pattern from those of Ambon and Seram, notably by the brown/orange throat and abdomen color (seen in live specimens), as well as having more evident dorsal rosettes.

Conclusions

Recent research on Indonesian monitors has relied heavily on colonial-era museum voucher specimens and recent animals obtained from the pet-trade (Böhme and Ziegler 1997; Philipp et al. 1999; Somma and Koch 2012; Ziegler et al. 2007a, b). This has obscured the fact that some of the newly described island endemics such as *V. melinus*, *V. cerambonensis*, and *V. rainerguentheri*, are not previously unknown animals co-occurring with a widespread *V. indicus*, but are instead local forms previously assigned to a variable *V. indicus* that have now been recognized as separate taxa. This has inflated the number of species thought to be present, with several islands allegedly harboring multispecies communities. Although we cannot rule out the possible existence of additional secretive species we conclude that there currently is no evidence for more than one species of mangrove monitor in the central Moluccas.

To avoid future confusion in the taxonomic and biogeographic interpretations of this group we call for more critical scrutiny of unique colonial-era museum specimens with single-word localities and no further supporting information.

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Appendix 1

Naturalis Museum specimens and scalation data included in the PCA.

Catalog number	Island	P	Q	XY	m	S	T	N	R
ZMA 10202	Alkmaar Island	44	78	134	82	131	90	75	60
RMNH 7297a	Ambon	48	89	150	105	140	96	86	56
RMNH 7297b	Ambon	47	81	146	100	140	95	83	52
RMNH 7297d	Ambon	52	85	152	104	142	94	84	54
RMNH 7297e	Ambon	48	80	139	104	138	93	81	51
RMNH 7297f	Ambon	51	79	148	101	131	95	79	50
RMNH 7297g	Ambon	50	87	153	105	146	100	85	53
RMNH 7196	Ambon	51	88	149	96	141	96	88	57
RMNH 3152	Ambon	51	89	154	110	143	100	90	56
RMNH 3150	Ambon	54	82	138	110	142	97	86	49
RMNH 3800	Bacan	42	80	134	88	128	91	85	57
RMNH 21031g	Biak	40	80	125	92	131	87	83	64
RMNH 21031h	Biak	39	79	124	94	128	86	77	61
RMNH 21033	Biak	42	76	122	92	135	86	81	62
RMNH 21026a	Biak	37	78	127	94	128	83	82	60
RMNH 21026b	Biak	37	80	121	88	126	86	84	61
RMNH 21024	Biak	38	74	115	88	122	84	77	58
RMNH 21021	Biak	42	79	123	90	122	85	79	64
RMNH 7223	Buru	46	79	147	95	145	95	78	55
ZMA 15416a	Buru	46	84	192	104	151	104	84	58
ZMA 15416b	Buru	46	83	187	95	141	104	86	58
ZMA 15416c	Buru	49	93	178	94	138	103	85	60
ZMA 15416d	Buru	48	88	187	90	150	100	90	68
ZMA 15416e	Buru	48	83	179	99	142	100	85	58
ZMA 15416f	Buru	46	85	183	98	143	101	83	54
ZMA 15416g	Buru	44	82	164	96	143	96	81	52
ZMA 15416h	Buru	47	83	174	93	142	103	86	60
ZMA 15416i	Buru	52	82	179	94	135	105	81	49
ZMA 15416j	Buru	44	75	159	91	142	95	81	53
ZMA 15414a	Halmahera	38	77	163	90	128	91	91	56
ZMA 15414b	Halmahera	43	82	155	89	139	93	85	61
ZMA 15414c	Halmahera	42	80	147	92	132	91	87	60
RMNH 7197	Haruku	46	89	144	101	142	97	88	50
RMNH 21041	Insoemarr Island	41	74	120	86	121	79	74	53
RMNH 21045	Japen	39	66	107	85	106	76	67	45
RMNH 21052	Japen	38	69	105	79	120	81	69	45
RMNH 21053	New Guinea	39	75	113	71	107	74	76	56
RMNH 21054	New Guinea	38	63	105	75	108	73	73	50
RMNH 21055a	New Guinea	41	70	111	83	109	77	74	56
RMNH 21047	New Guinea	40	73	115	79	113	85	77	57
RMNH 21042	New Guinea	43	70	115	83	113	79	76	52
RMNH 21046	New Guinea	39	76	110	81	110	77	77	58
RMNH 21036a	New Guinea	40	70	116	78	110	80	78	54
RMNH 21036b	New Guinea	41	73	116	81	110	80	74	58
RMNH 21036e	New Guinea	41	75	114	80	112	78	76	60
ZMA 10201	New Guinea	42	81	131	88	125	92	78	69

Appendix 1 (continued)

Naturalis Museum specimens and scalation data included in the PCA.

Catalog number	Island	P	Q	XY	m	S	T	N	R
ZMA 10208	New Guinea	43	72	125	73	114	90	73	65
RMNH 21037	New Guinea	42	75	128	80	128	92	76	58
RMNH 21038	New Guinea	41	68	118	80	118	87	72	60
RMNH 21034	New Guinea	44	82	128	85	123	85	77	66
RMNH 21046	New Guinea	44	70	129	84	120	87	72	53
RMNH 5359	New Guinea	41	80	115	80	113	88	72	67
RMNH 21018	New Guinea	41	77	115	78	112	84	71	62
RMNH 21050	New Guinea	41	75	118	87	116	79	72	62
RMNH 6726	New Guinea	43	73	121	82	122	80	85	59
RMNH 21040	New Guinea	40	76	128	81	122	87	78	59
RMNH 21020	New Guinea	40	78	123	84	125	83	74	65
ZMA 10194b	New Guinea	48	85	143	89	136	91	83	68
ZMA 10194c	New Guinea	42	77	124	81	122	95	77	68
ZMA 10200	New Guinea	42	66	121	73	115	74	75	46
RMNH 21035	New Guinea	42	73	119	78	111	81	73	52
RMNH 5260	New Guinea	36	60	116	74	110	82	73	51
RMNH 21048	New Guinea	45	74	113	80	115	84	67	56
RMNH 3151	Ravak	40	76	139	82	115	82	80	58
RMNH 3189	Seram	53	91	152	100	150	96	91	60
RMNH 3190a	Ternate	43	78	136	88	120	93	92	57
RMNH 3190b	Ternate	44	81	133	94	128	90	86	59
ZMA 15417	Ternate	43	76	140	85	127	94	87	58
ZMA 11146c	Unknown	43	72	140	80	123	87	76	59
ZMA 11146d	Unknown	42	70	131	79	121	84	73	61
ZMA 10192a	Waigeo	47	77	146	90	122	91	87	62
ZMA 10192b	Waigeo	48	82	151	82	123	91	80	64
ZMA 10192c	Waigeo	42	71	138	85	120	86	82	56
ZMA 10192d	Waigeo	48	73	147	78	119	86	84	61
ZMA 10192f	Waigeo	42	77	139	85	117	86	83	53
ZMA 10192g	Waigeo	42	77	141	79	125	86	80	54
ZMA 10192h	Waigeo	47	80	140	85	123	81	83	54